Experimental Evidence on the Effect of Insurance on Producer Behavior in the Face of Price Risk

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Abstract

Production risks can be caused by indirect factors such as weather, and direct factors such as price. Failure of constructing resilient financial markets to mitigate these price risks, can cause damaging and lasting impacts to the economy. This study contributes to the literature on risk and uncertainty by testing the effect of insurance, both full and partial, on producer behavior in the face of price risk. I use an experimental setting to addresses the relationship between behavior under price risk uncertainty, and how that behavior is shaped in the presence of insurance. I find that participants do not adjust their production choices in situations of price risk. When provided with insurance, they do increase production significantly, and reduce it when it is unavailable. The positive effect of full insurance, is higher than that of partial insurance. By comparing the effect of partial, and full insurance, I find evidence for moral hazard.

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1 Introduction

In the presence of risk, human behavior can cause individuals to react irrationally. While it seems intuitive for an individual to give a higher order of preference for positive outcomes with a higher certainty, this does not eliminate the possibility of risk taking behavior. In light of price uncertainty, providing insurance can lead producers to be risk averse. For example, increasing production when insured would be a clear indication of moral hazard for a risk averse producer. However, previous research has found that producers increase production in the case of price risk and uncertainty on the extensive margin (Bellemare et al., 2018); an increase in production could indicate risk taking behavior. While these two ideas have been studied, the dynamics of them occurring at the same time are unclear.

Production risks can be caused by indirect factors such as weather, and direct factors such as price. Failure of constructing resilient financial markets to mitigate these price risks, can cause damaging and lasting impacts to the economy. This is a growing concern especially for small farmers in developing countries, especially due to higher poverty rates, higher uncertainty in production, lack of credit, etc . Risk preferences are an empirical issue, and thus, experimental economics provides a foundation for estimating risk preferences. Although there have been several studies focusing on producer behavior under conditions of market uncertainty, None of them have observed, in an experimental setting, how that behavior would compare to a situation of price uncertainty with the availability of insurance. This study uses an experimental setting addresses the relationship between behavior under price risk uncertainty, and how that behavior is shaped in the presence of insurance.

Ganderton et al. estimate the willingness to pay for insurance and find that the probability of purchasing insurance increased with the probability of a loss, but the results from their experiment have a lack of generalizability. Laury et al. (2009) use experimental evidence and find confounding results to prior insurance purchasing literature, showing that individuals buy more insurance for lower-probability events than they buy for high-probability events, given constant expected losses. They find these results especially since people pay attention to risks when the likelihood of occurrence rises over a certain threshold. However, the uptake of buying insurance in several randomized controlled trials (RCTs) (Cole et al.(2013), Mobarak and Rosenzweig (2012), and Hill and Robles (2011)) has been consistently low, making insurance a difficult topic of study.

The theoretical model and protocol used of this paper, is mostly a replication of the study by Sandmo (1971). The experimental design is closest to the experiment by Bellemare et al. (2018) and is an extension of their experiment with an additional randomization stage of insurance. The paper proposes a four-stage randomization experiment. In the first stage, the producers are randomly assigned to either of the two situations of price certainty or price uncertainty. Then, the level of price risk is allowed to randomly vary in the cases of price uncertainty. Conditional on a set-up of price uncertainty, the producers are further randomly provided insurance. In the last stage, random assignment of partial or full insurance (conditional on insurance provision) is offered. Thus, producer output choice making behavior under price uncertainty is studied, followed by studying any change, if at all, in that behavior after presenting a situation of partial or full insurance.

This study contributes to the literature on risk and uncertainty by testing the effect of insurance, both full and partial, on producer behavior in the face of price risk. It is an attempt at collecting experimental evidence for testing these effects, which can be later used as a foundation to expand this methodology in the field for future lab-in-the-field experiments.

The results of this paper are in alignment with those found by Bellemare et al. (2018) in that participants do not adjust their production choices in situations of price risk. Interestingly, when provided insurance, they do increase production significantly, and reduce it when it is unavailable. The positive effect of full insurance, is higher than that of partial insurance. By comparing the effect of partial, and full insurance, I find evidence for moral hazard.

The remainder of this document proceeds as follows. The paper begins by reviewing past literature on insurance and producer behavior in the face of price uncertainty. Section 3 describes the theoretical framework. Section 4 explains the experimental design and the two games that subjects played in the lab. Then, in section 5, the descriptive statistics the data are stated followed by section 6 which explains the empirical model. In section 7, I discuss the experimental results. Section 8 summarizes the findings and concludes with discussing the future research that can follow in this direction.

2 Literature review

Most previous research on insurance has been related to a non-price index. Hazel et al. (2010), for example, talk about index insurances in several developing countries. However this paper focuses at situations where the price movements can be monitored and studied, resulting in scope for developing insurance which would help reduce the price risks. Hazell (1992) states that an insurable risk has three characteristic- the quantifiable nature of the likelihood of the event, easily attributable damage and no effect of behavior on occurrence or damage (eg, moral hazard) of the event. For this study, damage due price uncertainty can be measured by the probability of the uncertain settings, this damage is quantifiable by the losses to the farmers, which makes price risk an insurable risk.

Bellemare et al. (2018) have used experimental methods to test the dynamics of price risk, on the output levels which are endogenous to the agricultural producers. The purpose of this paper, is to extend the experimental methods used by Bellemare et al. (2018) to understand the role that partial and full insurance can play in deciding the output levels, conditional on uncertainty in the output prices. The study by Bellemare et al. (2018) is interesting in that their findings contradict the general intuition that producers reduce their production quantity in the face of price risk, as explored by Sandmo (1971). They study subjects in three experiments in Cornell, Minnesota and Peru and their results that at the extensive margin, price risk actually causes the producers to increase their production. Studies by Finkelshtain and Chalfant (1991) on the behavior of agricultural self-producing households find similar conclusions about invalidity of models of output price uncertainty. They find that in case of uncertainty, a producer may choose to over or under produce than the expected profit maximizing quantity.

These results give rise to some important questions such as what benchmarks are used by policy makers while implementing risk-related decisions, how do producers react to the output price and quantity risks and whether the existing insurance policies are enabling farmers in making the right production decisions. This paper attempts at addressing these questions under a lab setting of price risk uncertainty.

Studying insurance in an experimental setting is especially complicated because of two main hurdles. Firstly, the take-up for insurance is low (Cole et al, 2013). This leaves us with very low heterogeneity in the treatment and reduces the power for assessing the effects of insurance. This paper differs in that the case of ideal insurance is studied, thus eliminating the possibility of a low take up in addition to eliminating the case for adverse selection. Secondly, it is difficult to endogenously assign insurance. Attempts at studying moral hazard (Ramaswami, 1993) and willingness to pay usually have the limitation that it is difficult to separate the effect of insurance on decision making and the effect of other factors involved in production decision making. Since insurance is randomly necessarily offered to all participants and for free in this experimental design, it is easier to interpret the exogenous effects of insurance on production.

3 Theoretical Framework

The theoretical framework mimics Sandmo's (1971) paper where he considers producer's whose objective function is maximizing the expected utility of the profits. The utility function is assumed to satisfy the von Neumann-Morgenstern axioms. The average producer is assumed to be risk averse, and produces only one commodity. These conditions are used to study the effect of insurance on production behavior in an uncertain output price.

The concave, continuous and differentiable utility function $U(\pi)$ of the producer over her profits is such that $U'(\pi) > 0$ and $U''(\pi) < 0$. The profit function of the firm $\pi(x)$ is defined as $\pi = px - C(x) - FC$, where p is restricted to be risky and non-negative, $x > 0$, and expected value of output price $E[p] = \mu$. FC is the "fixed cost", $C(x)$ is the variable cost function which follows the assumptions $C(0) = 0$, and $C'(x) > 0$.

The producer makes production decisions *ex ante* of the determination of the output price. Therefore, the expected utility function of the producer is

$$\max_x E[U(px - C(x) - FC)] \tag{1}$$

The first-order and second-order conditions can be obtained by differentiating with respect to x as

$$E[U'(\pi)(p - C'(x))] = 0 \tag{2}$$

and

$$E[U''(\pi)(p - C'(x))^2 - U'(\pi)C''(x)] < 0 \tag{3}$$

Proposition 1 (Sandmo, 1971) *Under the assumptions stated above, a risk-averse producer will decrease production in the face of price uncertainty relative to a situation of price certainty where the price equals the mean of the price distribution.*

Proof Equation 2 can be re-written as

$$E[U'(\pi)p] = E[U'(\pi)C'(x))] \tag{4}$$

Subtracting $E[U'(\pi)\mu]$ on both sides we get

$$E[U'(\pi)(p - \mu)] = E[U'(\pi)(C'(x) - \mu)] \tag{5}$$

Since $E[\pi] = \mu x - C(x) - FC$, from how profits are defined, by rearranging terms we can get $\pi = E[\pi] + (p - \mu)x$. This implies that the difference in expected and realized profits is only because of the *ex post* price p and the producers expectation of the price μ. The production decisions are made based on the expected *ex post* price by the producer. If the two prices are equal, $p = \mu$, then $E[\pi] = \pi$, i.e. the expected profits equal the realized prices, which will certainly be the case in the experiment with rounds of price certainty.

If $p \geq \mu$, then $U'(\pi) \leq U'(E[\pi])$. Therefore,

$$U'(\pi)(p-\mu) \leq U'(E[\pi])(p-\mu) \tag{6}$$

which holds for all values where $p \geq \mu$. Taking expectations on both sides of equation 6,

$$E[U'(\pi)(p-\mu)] \leq U'(E[\pi])E[p-\mu] \tag{7}$$

The right-hand side equals zero since $E[p-\mu] = E[p] - \mu$ and $E[p] = \mu$ by definition. This implies that the left-hand side of equation 7 is negative. Substituting this in equation 5, $E[U'(\pi)(C'(x) - \mu) \leq 0$, which means that $C'(x)/leq\mu$, and the optimal output is characterized by marginal cost being less than the marginal benefit of producing that output. This establishes the result that when the price is uncertain, the producers produce lesser than they would, in the case of certain price.

4 Methodology and Experimental design

The experiment has nine study arms. First, there is the randomization of price uncertainty. Which makes the first five study arms- price certainty, and the four levels of price uncertainty. The sixth and seventh arms are insurance provision and no insurance provision. Lastly, partial insurance, or full insurance make up the eighth and ninth study arms.

The participants play two games, and their payoffs are a sum of the payoffs from each of these individual games. The average payoff for these experiment games is \$56. This ensures a high monetary incentive for the participants to be truthful and honestly involved in the games. The two games are described below-

4.1 Price-Risk-Insurance Game

This is the game that the participants played in the lab experiment. It is a close replication of Sandmo's (1971) theoretical design, and Bellemare et al.'s (2018) experimental design. The set up for decision making is described as a list of procedures. Then, a method of studying the risk preferences of the subjects is explained which is the lottery choice game used by Holt and Laury (2002).

The participants were asked to pose as producers of a commodity (wheat, in the lab experiment). First, the participants play 5 practice rounds. Then, they play 25 rounds of the actual experiment. During the practice rounds, the participants are encouraged to ask questions, to enable a better comprehension of the game. Randomization is pre-done.

Simple cost and profit functions are used . The fixed cost F is set as $F = 15$. The variable cost function $c(x)$ is set as $c(x) = 2x^{1.4}$. This functional form used to mimic Bellemare et al.'s (2018) set up, and to comply with the theoretical set up of Sandmo (1971). The profit function $\pi = px - 2x^{1.4} - 15$. To help them make decisions, charts displaying the various combinations of output choices, costs, and profits were handed to the participants. A combined chart for all the possible prices and outputs and the corresponding outputs was also provided. These charts can be found in Appendix B, section 2.

The randomization process and the price risk game was played in the following four stages of the game-

1. Uncertainty- The first stage of randomization was determining price uncertainty. In one-third of the 25 rounds (8 rounds, specifically), the subjects faced price certainty and thus the price of output would surely be \$7 per bushel of wheat. In the rest of the two-third rounds (17 rounds), the price was uncertain ranging from \$5-\$9 per bushel. The participants were told whether they were in a price certain or price uncertain setting.

2. Level of price risk- After the determination of price uncertainty, there were four possible levels of price risk. Section 2 of Appendix B displays the various

price settings show the five distributions and levels of risk that participants could face. Setting 1 corresponds to price certainty. For each uncertain round, one of the other four settings was randomly chosen. The participants were told which level of price risk they were facing and had access to the figure on their screens. The average price in all the five total settings was \$7. The mean-preserving spreads were used in the price distributions to be consistent with Sandmo's (1971) set-up.

3. Insurance- The third stage of randomization was determining insurance. In one third of the uncertain rounds (6), no insurance was offered. In the rest of the two third rounds (11), insurance was offered for some or all of the losses that would occur by choosing a production level. At this point, participants would know whether they were in an uncertain situation, what the level of risk they had, and whether they had insurance.

4. Level of insurance- The last stage of randomization was the level of insurance. For half of the uncertain rounds with insurance, participants were given full coverage for their losses while in the other half, 50% or half of their losses were covered. The participants knew whether they had price uncertainty, what level of uncertainty, and whether they would be fully or partially covered for losses, in case.

The participants made *ex ante* production decisions after knowing the price and insurance situation they were in, but the *ex post* price in the uncertain settings was determined only after the production decisions were made, by randomly drawing a ball from the setting.

The software O-tree was used to facilitate the experiment. Each participant had their own computer screens which displayed the four things mentioned above. All the participants played the same round, and a common price was drawn for all the participants. The software ensured that moving to the next screen of price determination was only permitted after all the participants had entered their production choices, so as to keep everyone on the same pace throughout the experiment.

At the end off the 25 actual rounds, one of the rounds was randomly chosen by the participant, by drawing a ball from a bag. The participants received a base payoff of $30 for showing up. In addition to that, the payoffs were calculated as a base pay-off of $25 plus half of the profits they made. If they made a loss, and if the round had full insurance, then they get to keep all of the $25. Whereas in the case of a loss and partial coverage, half of their loss would be covered and they would lose half of the total half.

4.2 Holt-Laury List Game

The second game the participants played was the Holt-Laury list experiment. Sandmo's conclusions about production focus on risk averse participants. Thus, determining the level of risk aversion for the participants was important to follow Sandmo's (1971) experiment design. I used the experiment designed by Holt and Laury (2002) for eliciting the level of risk aversion for the participants.

For this game, the participants were given a set of lotteries to choose from. Section 1 of Appendix B displays the Holt-Laury game. The participants were shown a list of ten rows. Each row had two sets of lotteries which are given as the two options on the columns, A and B. The participants have to choose one of the two options for each row. The options in column A are always less risky than options in column B, and therefore more attractive to risk aversion. The expected payoffs for option A are higher than expected payffs from option B in the beginning, but the gap reduces as you go down the rows.

The game is designed in a way to make the participants switch from column A to column B. Once the participant chooses column B, the game ends. I only allow for monotonic switching, so as to ensure that the assumptions of EU theory are satisfied. This method is incorporated from Bellemare et al. (2018), and Magnan et al. (2018).

The payoffs for the Holt-Laury game are determined as follows. First, the participant rolls a ten sided die to determine which of the ten rows would determine the lottery to be played by the participant. Then, the ten sided is rolled again to actually play the lottery to determine the payoff for this game.

5 Data and descriptive statistics

The participants for this experiment were recruited using the Carlson School of Management Paid Subject Pool, and the experiment was conducted in the Social and Behavioral Sciences Laboratory at the University of Minnesota, Twin Cities. The subject pool was diverse in age, education, and gender.

There were 28 participants in total, and each participant played 25 rounds of the actual game. Together, this gives a pooled sample of N=700 observations which are used in studying results of the experiment. Table S1 displays data on the descriptive statistics for the sample. On average, the price for the rounds was 7, which is intuitive because of the experimental design. The average production units were 11, and the median production units were 10. This also makes sense, since the profit maximizing quantity for price 7, is 10 units.

The Figures 1 through 6 are histograms displaying the level of production for the different scenarios. Fig. 1 shows the output for all the rounds combined. The profit maximizing output choice for $7 is 10 units, which is the highest frequency output choice. Recollect that the price distributions were mean-preserving spreads around $7. Fig 2. shows the output choices for the rounds where there price uncertainty. Figures 3 and 4 show the output choices for insurance and no insurance, respectively. As expected, the output choices for insured rounds are more on the higher side than the uninsured rounds. Figures 5 and 6 show the outputs for partially and fully insured rounds, respectively. The higher output choices for insured rounds seems to be driven more by the fully insured rounds.

6 Empirical Framework

Variables of interest and the proposed model

The most important variable of interest in the experiment, is the output choice that the subjects make. In each round, the subjects make production output decisions. The subjects were informed that their production behaviors are independent of the behaviors of other peer producers. It is important to note that these output decisions were made made after the determination of the setting and the insurance situation; however, the output decisions were made *ex ante* of the realization of the price that the subjects would get for their output choices.

The risk preferences derived from the Holt-Laury game, the Arrow-Pratt coefficient of relative risk aversion (CRRA) is obtained, which is used to estimate the marginal effect of risk aversion on output choices. Following Holt and Laury's recommendations (2002), constant relative risk aversion (CRRA) is assumed and I obtain R_i which is the Arrow-Pratt coefficient of relative risk aversion for individual i. I assign R as follows: $R =$ -0.95 to subjects who switch in the first line of the Holt-Laury list experiment, $R =$ -0.49 to subjects who switch in the second line, $R =$ -0.15 to subjects who switch in the third line, $R =$ 0.15 to subjects who switch in the fourth, $R =$ 0.41 to subjects who switch in the fifth line, $R =$ 0.68 to subjects who switch in the sixth line, $R =$ 0.97 to subjects who switch in the seventh line, $R =$ 1.37 to subjects who switch in the eighth line, $R =$ 1.50 to subjects who switch in the ninth or tenth line. The next subsection describes these desired effects and models the equation of interest for the game. This work follows the framework from Bellemare et al.'s (2018) paper and extends their analyses by adding insurance to it. It is obvious that in the case where full insurance is offered, the producers will produce at least as much as they would have produced under the price certainty situation. In the case where partial insurance is offered, the producers are expected to make production decisions in an intermediate level between price risk and price certainty. For testing Sandmo's assumption that uncertainty results in decreased production, I test the following equation-

$$y_{it} = \alpha + \beta_1 I(\sigma_t > 0) + \delta_1 R_i + \theta_1 x_i + v_i + \epsilon_{1it} \tag{8}$$

Where, y_{it} is subject i's output choice in round $\tau \in (1,\ldots,25)$, $I(\sigma_t > 0)$ is a dummy variable which equals one if subjects are making that output decision in face of price risk and equals zero otherwise, R_i denotes subject i's Arrow-Pratt coefficient of relative risk aversion which is obtained from the Holt-lottery game, x_i is a vector of control variables specific to subject i (eg. age, sex, education, ethnicity), v_i is a random effect specific to subject i, and ϵ_{1it} is an error term with mean zero.

For testing Sandmo's assumption of uncertainty and decreased production, the following hypothesis will be tested in the experiment, H_0: $\beta_1 = 0$. If the effect is significantly different from zero, then the null would be rejected in favor of the alternative. Additionally, if this effect is also negative, then this would be analogous to Sandmo's results.

I add two more specifications- the effect of uncertainty and insurance; uncertainty and partial insurance and uncertainty and full insurance. The following specification tests for uncertainty and insurance (insurance could be either partial or full)-

$$y_{it} = \alpha + \beta_2 I(\sigma_t > 0) + \delta_2 R_i + \theta_2 x_i + \gamma_2 I(\sigma_t > 0) * I(\kappa_t > 0) + v_i + \epsilon_{2it} \tag{9}$$

The variables are defined as above, and $I(\sigma_t > 0) * I(\kappa_t > 0)$ is the interaction term between uncertainty and insurance. In this specification, I am interested in testing the hypothesis- H_0: $\gamma_2 = 0$. The rejection of this hypothesis will tell us that insurance has an effect on production in the presence of uncertainty. The direction of γ_2 will tell us whether insurance under uncertainty has a positive or a negative effect on production.

The last specification I test is-

$$\begin{aligned} y_{it} = &\alpha + \beta_3 I(\sigma_t > 0) + \delta_3 R_i + \theta_3 x_i + \gamma_3 I(\sigma_t > 0) * PI(\lambda_t > 0) + \\ &\eta_3 I(\sigma_t > 0) * FI(\phi_t > 0) + v_i + \epsilon_{3it} \end{aligned} \tag{10}$$

The variables are defined as above, $I(\sigma_t > 0) * I(\lambda_t > 0)$ is the interaction term between Uncertainty and Partial Insurance, and $I(\sigma_t > 0) * I(\phi_t > 0)$ is the interaction term between Uncertainty and full insurance. In this specification, we are interested in testing the following two hypotheses-H_0: $\gamma_3 = 0$, and H_0: $\eta_3 = 0$. The rejection of this hypothesis will tell us the effects of partial and Full Insurance on production in the presence of uncertainty. The direction of γ_3 and H_0: $\eta_3 = 0$ will tell us whether partial and full insurance under uncertainty have a positive or a negative effect on production. Note that in the last specification, I do not have the variable $I(\sigma_t > 0) * I(\kappa_t > 0)$ as was in equation 9 because full or partial insurance were only offered in the rounds that had insurance. Additionally, the experiment design had no cases where the price was certain and insurance was offered, which explains why there is no interaction term between certainty and insurance in any of the equations.

The randomization is on subject-level and each subject is followed through the 25 rounds. I use the random effects model to estimate the results and cluster errors at the individual level, as Abadie et al. (2017) suggest in their paper.

7 Experimental results

This section follows three parts. In the first part, I discuss the results from Sandmo's predictions (i.e. equation 1), and check if the data follow his prediction that price risk at the extensive margin causes a reduction in production level. Second, I study how Sandmo's predictions differ when the producers are provided with insurance (equations 2 and 3). Then, I estimate the same three equations for a subset of the sample, restricting it only to risk averse participants. The risk averse participants are those whose $R > 0$, or switching point for the Holt-Laury list game was after row 4.

Since all the subjects saw the same sequence of rounds, it is possible that there exist some order effects. To account for that, I calculate the results using fixed effects and present them in table S4. However, after running a Hausman test pitting the specifications in the table S2 against the same specification but with subject specific fixed effects, I fail to reject the null with a p-value of 1.00. I believe this constitutes strong evidence that random effects are preferred in this context, since random effects are more efficient. Thus, the remainder of the paper proceeds using results from the random effects model.

Using the experimental design, I find little or no evidence to support Sandmo's claim, indicating some invalidity of expected utility theory for this context. The results in column (1) of Table S2 indicate that participants do not make significantly different output decisions in the presence of uncertainty (at the extensive or the intensive margin). However, in the presence of insurance, significant behavioral changes are observed. Column (2) of Table S2 shows that production is decreased by 1.387 units, when the participants know that the particular round insures a part or all of their losses. Complementing evidence for the existence of moral hazard, is the effect of the interaction term between uncertainty and insurance on production. When participants are offered insurance in the uncertain price rounds, they increase production by 2.926 units. Since all the participants were forced to have insurance in the rounds that it was offered in, we can rule out the role of market asymmetry in terms of adverse selection. The significance of both the coefficients on uncertainty and the interaction term indicate the existence of moral hazard.

In column (3) of Table S2, the difference in the positive magnitudes of partial and full insurance supports the claim for moral hazard and is intuitive. When the losses are fully insured, participants increased production by 4.333 points as compared to increasing it by 1.783 point with partially insured losses. The coefficient of uncertainty is negative which indicates that participants behave in a risk averse way uncertain rounds when partial and full insurance are controlled for.

Another interesting result is that the positive effect of insurance under uncertainty is higher than the negative effect of uncertainty. In Table S2, we can see that after controlling for insurance, price risk has a significant negative on the output. However, giving insurance to cover the losses due to the uncertainty, significantly increases production. This increase in production due to insurance for uncertainty is almost twice in magnitude of the decrease in production due to uncertainty. Thus there is a very high negative effect of uncertainty in the absence of insurance.

In Table S3, data for only the risk averse participants was used to calculate the equations 1 through 3. Interesting and paradoxical results are observed, since risk averse subjects are behaving like risk loving, both for uninsured and insured situations. Column (1) in Table S3 shows that under uncertainty, the risk participants increase production. In Column (2), when insurance is provided, then production is significantly increased, by 3.136 units. And the impact of full insurance is almost four times that of partial insurance.

8 Conclusion and Discussion

This study is unique in that it is one of the first attempts at testing price risk and heterogeneous insurance coverage in an experimental lab setting. The experiment is an extension of Bellemare et al. (2018) and mimics the experimental design of

Sandmo (1971). I find similar results to Bellemare et al. (2018) in that there is no significant change in production due to uncertainty at the extensive margin. However, when insurance is provided, the production is significantly increased, whereas a reduction in production is observed when there is no insurance available for the losses.

These results show that there could be some role of moral hazard in the production decisions made under uncertainty and insurance availability. However, provision of insurance could be an incentive for increasing production, in an ideal setting. Since this experiment was conducted in a lab with mostly undergraduate students, one could argue about the external validity of the results. Studying insurance in the developing world is especially of growing interest now, and whether similar results would be obtained if this experiment is conducted with farmers from a developing country is a question worth exploring. Conducting lab-in-the-field experiments of similar kind could be great addition to the literature of price risk and insurance.

In this experiment, insurance was provided for no cost, and the participants had to make decisions assuming that they would not have to bear any cost for the insurance. It would be valuable to see the impact of insurance when participants have to pay some price for purchasing insurance, and even better if that price could be randomly provided at discounted prices. Braun and Muermann (2004) find interesting results about regret theory. It would be interesting to see the interactions of regret-aversion, in the context of price risk and Expected Utility Maximization (EUT). Lybbert et al. (2010) find that effects of risk aversion on insurance are significantly negative, since risk averse people would choose self-financing, which is the least risky choice, in the absence of free insurance. Experimentally testing these two ideas along with offering insurance at discounted prices would be good directions to take this research in.

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10 Appendix A

Table S1: Descriptive Statistics (n=700)

Variable	**Mean**	**(Std. Dev.)**	**Min**	**Max**
Output Level	11.04	(2.46)	0	20
Price	6.68	(1.11)	5	9
Uncertainty	0.70	(0.46)	0	1
Standard Deviation	0.84	(0.68)	0	1.58
Profit	2.86	(11.61)	-43.39	31.99
Holt-Laury Switch Point	7.21	(1.51)	2	10
Age	31.07	(0.94)	19	68
Female	0.42	(0.49)	0	1
Insurance	0.44		0	1
Partial Insurance	0.24		0	1
Full insurance	0.2		0	1

Table S2: Random Effects Regression Results for the entire Sample

Variables	**(1)**	**(2)**	**(3)**
	Dependent variable: Output		
$I(\sigma > 0)$, or Price Risk	0.454	-1.387***	-1.374***
	(0.554)	(0.510)	(0.510)
Arrow-Pratt Coefficient of RRA	-0.167	-0.167	-0.167
	(0.465)	(0.466)	(0.466)
Female	-0.912**	-0.912**	-0.912**
	(0.430)	(0.430)	(0.431)
Age	-0.0478***	-0.0478***	-0.0478***
	(0.0116)	(0.0116)	(0.0116)
$I(\sigma_t > 0) * I(\kappa_t > 0)$ or Price Risk*Insurance		2.926***	
		(0.284)	
$I(\sigma_t > 0) * I(\lambda_t > 0)$ or Price Risk*PartialInsurance			1.783***
			(0.249)
$I(\sigma_t > 0) * I(\phi_t > 0)$ or Price Risk*FullInsurance			4.333***
			(0.397)
N	700	700	
R^2 Overall	0.011	0.16	0.24
Individual FE	YES	YES	YES
Round FE	YES	YES	YES

Standard errors in parentheses, clustered at the subject level

$^{***}p < 0.01$, $^{**}p < 0.05$, $^{*}p < 0.1$

Table S3: Random Effects Regression Results for the risk-averse only Sample

Variables	**(1)**	**(2)**	**(3)**
Dependent variable: Output			
$I(\sigma > 0)$, or Price Risk	0.985***	-0.987***	-0.973***
	(0.281)	(0.272)	(0.272)
Arrow-Pratt Coefficient of RRA	-1.934**	-1.934**	-1.934**
	(0.804)	(0.805)	(0.806)
Female	-0.475	-0.475	-0.475
	(0.326)	(0.327)	(0.327)
Age	-0.0165	-0.0165	-0.0165
	(0.0107)	(0.0107)	(0.0107)
$I(\sigma_t > 0) * I(\kappa_t > 0)$ or Price Risk*Insurance		3.136***	
		(0.258)	
$I(\sigma_t > 0) * I(\lambda_t > 0)$ or Price Risk*PartialInsurance			1.882***
			(0.255)
$I(\sigma_t > 0) * I(\phi_t > 0)$ or Price Risk*FullInsurance			4.678***
			(0.335)
N	700	700	700
R^2 Overall	0.011	0.16	0.24
Individual FE	YES	YES	YES
Round FE	YES	YES	YES

Standard errors in parentheses, clustered at the subject level

***$p < 0.01$, **$p < 0.05$, *$p < 0.1$

Table S4: Fixed Effects Regression Results for the entire Sample

Variables	(1)	(2)	(3)
	Dependent variable: Output		
$I(\sigma > 0)$, or Price Risk	0.454	-1.387**	-1.374**
	(0.550)	(0.506)	(0.507)
$I(\sigma_t > 0) * I(\kappa_t > 0)$ or Price Risk*Insurance		2.926***	
		(0.282)	
$I(\sigma_t > 0) * I(\lambda_t > 0)$ or Price Risk*PartialInsurance			1.783***
			(0.247)
$I(\sigma_t > 0) * I(\phi_t > 0)$ or Price Risk*FullInsurance			4.333***
			(0.394)
N	700	700	
R^2 Overall	0.010	0.178	0.269
Individual FE	YES	YES	YES
Round FE	YES	YES	YES

Standard errors in parentheses, clustered at the subject level

$^{***}p < 0.01$, $^{**}p < 0.05$, $^{*}p < 0.1$

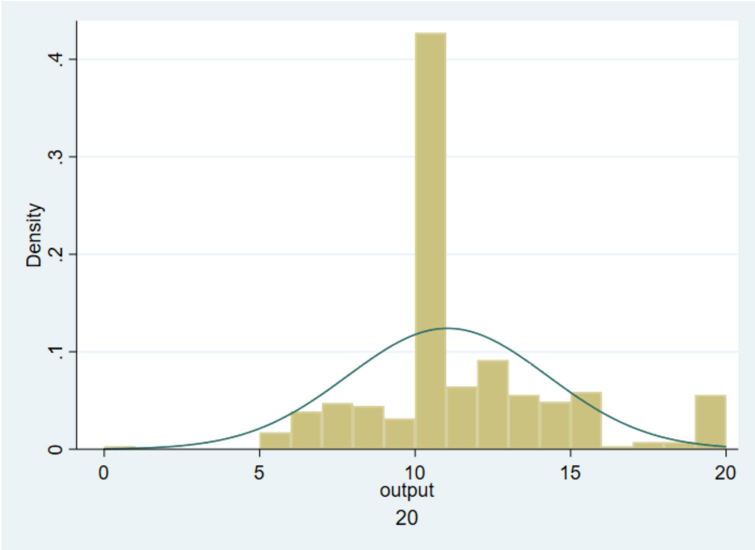

Figure 1: Output-All

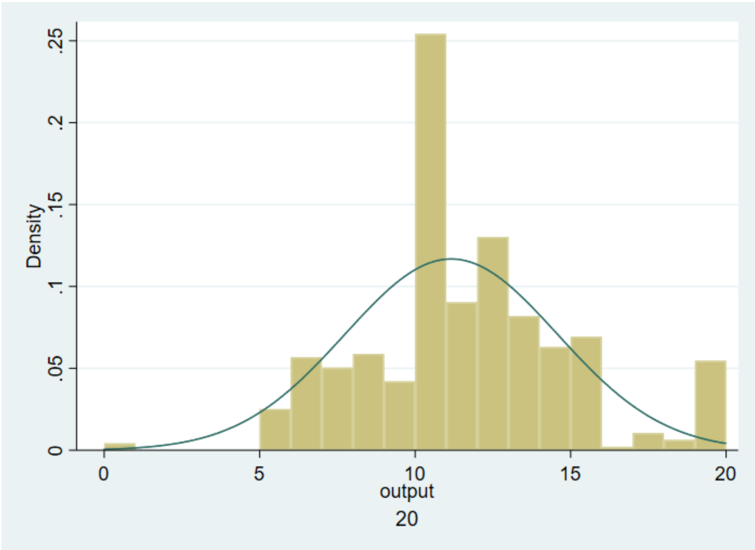

Figure 2: Uncertain rounds

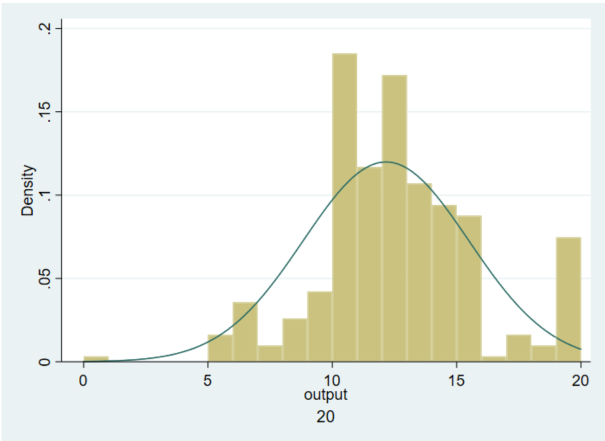

Figure 3: Insured rounds

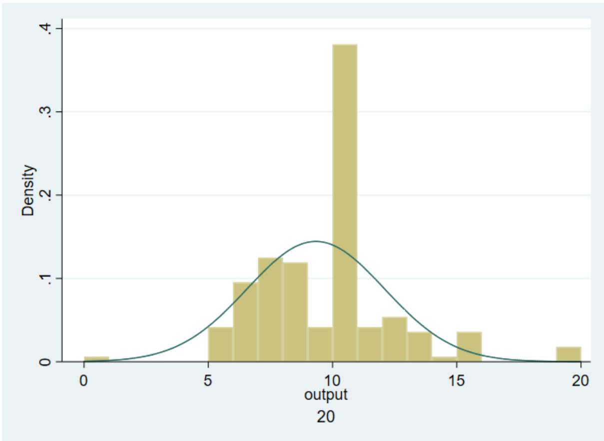

Figure 4: Uninsured rounds

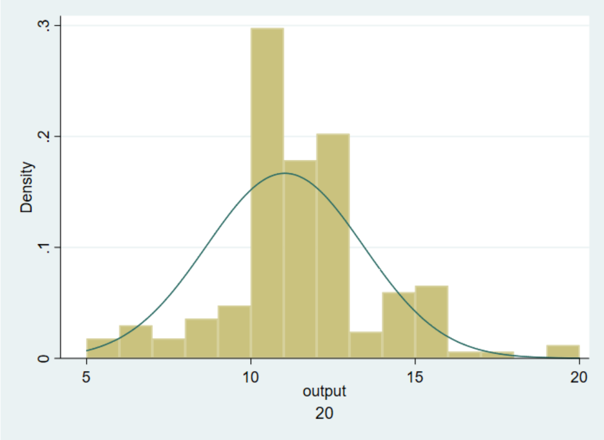

Figure 5: Partially Insured rounds

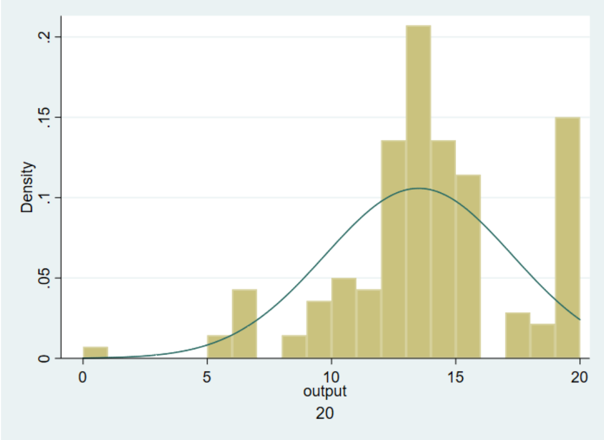

Figure 6: Fully Uninsured rounds

11 Appendix B: Experimental Protocol

1- Consent Form, Instructions, and Lottery Choice game answer sheet

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Consent Form

This study involves research in economics and it is being conducted by researchers from the University of Minnesota. The purpose of this study is to test some of the predictions of economic theory. You will spend 170 to 180 minutes in the laboratory playing economic games for money.

We will "endow" you with an amount of money ($30 plus $25) which you will use in playing the economic games you will be playing as part of this experiment. Depending on your performance as part of those experimental games, you may win additional money or lose some of the $25 portion of your endowment. In some cases, you would receive full or partial insurance, in which your losses or a part of your losses will be on us. You will, however, go home with at least $30 to compensate you for your time. Note, however, that you might go home with an additional $1.31 to $45.16 depending on your performance. Beyond that, there is no direct benefit to participation.

You will face minimal risk by participating in this experiment: the risks include loss of confidentiality and potential embarrassment associated with losing money. You will feel no discomfort at all.

The benefits of this research will be to validate an important and hitherto neglected aspect of economic theory as well as to inform policy makers about an important area of economic policy.

In the interest of confidentiality, we will not be recording your name, but we will be recording some demographic information about you (e.g., age, gender, level of education), and we will obviously be recording your actions in the experimental economic games we will have you play. It will not be possible from the data to tell who you are, and so all the data provided here today is confidential in its strictest sense.

For more information, please contact the Principal Investigator, Professor Marc F. Bellemare, Department of Applied Economics, University of Minnesota, by writing to him at mbellema@umn.edu or calling him at 612-624-1692. You may also contact Ms. Aditi Kadam, Masters student, Department of Economics, University of Minnesota, by writing to her at kadam020@umn.edu or calling her at 319-575-3920.

Your participation is voluntary, and your refusal to participate will involve no penalty or decrease in benefits to which you are otherwise entitled outside of this experiment. Moreover, you may discontinue participation at any time without penalty or loss of benefits to which you are entitled outside of this experiment.

Name (please print): ____

Date: ____

Signature: ____

General Instructions

- This is an experiment in the economics of individual decision making. We are trying to understand how people make production decisions when they are unsure of the price they will receive and when they are provided insurance. We have designed simple decision-making games in which we will ask you to make choices in a series of situations.
- There are two sets of games. In the first set of games, you will be making decisions assuming that you are a farmer producing a single commodity, wheat. In the second set of games, you will be given a series of lotteries to choose from. More detailed explanations will follow in each set.
- You will spend 170 to 180 minutes in this study playing economic games. You will automatically receive $30 for participation and in addition may earn between $1.31 and $45.15 depending on your performance and also on the luck on the experiment. The amount will be transferred on a debit card which will be given to you.
- You should make your own decision and should not discuss your decisions or the decision scenarios with other participants. Also, please turn off your cell phones.
- You need to have a good understanding on how your decisions affect your payoff. Please raise your hand at any time during the session if you have any question.
- You can access more information about how to use the debit card here- http://prepaid.umn.edu

Set I: Single-Commodity Production Game

- You are a farmer who produces and sells only one commodity, wheat.
- The selling price of wheat in dollars per bushel will be one of the five possible values: $5, $6, $7, $8, and $9, and it will be realized *after* provision (or no provision) of insurance and *after* you make your production decision to reflect the real-world output price uncertainty.
- You will be given charts 1 through 5 which document the amount of cost to be incurred according to production levels 0 through 20 (in 1,000 bushels), and the corresponding profit (in $1,000) that will occur *under the five different price scenarios*. These charts contain all the information about how your production decision, cost of production, and your profit relate to one another. Chart 6 is a summary of charts 1 through 5 and shows only the relationship between the production level and the profit.
- In each round, you will be given one of the four situations: (1) You know that your selling price will be exactly $7; (2) You will be provided full insurance and you know that the price will be one of the five values -- $5, $6, $7, $8, and $9; (3) You will be provided partial insurance and you know that the price will be one of the five values -- $5, $6, $7, $8, and $9; (4) You will not be provided insurance and you know that the price will be one of the five values -- $5, $6, $7, $8, and $9. Under a given situation, you will be asked to determine how much wheat to produce by choosing any integer between 0 and 20 as your production level. You may refer to the charts 1-6 to facilitate your decision.
- Note that provision of insurance means you will be fully or partially covered for all your losses.
- Your goal is to maximize the profit (price times quantity produced minus cost of production), since maximizing profit is identical to maximizing your payoff.
- Note that there is no subsistence constraint, meaning that there is no minimum required level of production for your survival. Nor is there a requirement to make a positive profit in order for you to survive. Negative profits mean that you lose some of the money that you are endowed with.
- *After* provision (or no provision) of insurance and *after* you have chosen how much to produce, a ball will be drawn randomly from a bag, which will determine your selling price. You will sell your wheat at that price, which will determine your profit.

- You will first play 5 rounds of practice games. After the practice games, you will play 30 rounds of the real games. In the real games, your payoff will affect your profits from the games.

- In this set of the game, you start from base payoff of \$25. In a given round, your profit will be between -47.58 and 32.61. After the 25 actual rounds, we will randomly select a round. Your payoff from these games will be determined in the following way:

- In a case that the selected round had no insurance provided, your final pay off will always be: \$25 base payoff + a half of your profit in the randomly selected round. For example, if you have made a loss of 30 in the selected round, your final payoff will be \$25 + (-\$30 X 0.5) = \$10. If you have made a profit of 28, your final payoff will be \$25 + (\$28 X 0.5) = \$39.

- In a case that the selected round had full insurance provided, your final pay off will always be: \$25 base payoff. For example, if you made a loss of 30 in the selected round, your final payoff will be (-30) + (25) = \$25.

- In a case that the selected round had partial insurance provided, your final pay off will always be: \$25 base payoff + half of half of the losses in the randomly selected round. For example, if you made a loss of 30 in the selected round, your final payoff will be \$25 + (-\$30 X 0.5 X 0.5).

- Your final payoff in this set of the games will range between \$1.31 and \$41.31.

Set II: Lottery Choice Game

- In this set of games, you will be presented a table of ten paired lotteries, A and B, from which you are asked to choose one that you prefer.
- Below is an example of the options that you will be given:

Option A	Option B
1/10 of \$2.00, 9/10 of \$1.60	1/10 of \$3.85, 9/10 of \$0.10

  If you choose option A, there is a probability of 0.1 that you will be receiving \$2.00, and a probability of 0.9 that you will be receiving \$1.60. If you choose option B, there is a probability of 0.1 that you will be receiving \$3.85 which is much bigger than \$2.00 in option A. However, there is also a 0.9 probability that you will be receiving only \$0.10.

- Stop once you have chosen the option B.
- Here is a ten-sided die that will be used to determine payoffs; the faces are numbered from 1 to 10 (the "0" face of the die will serve as 10.) After you have made all of your choices, we will throw this die twice, once to select one of the ten decisions to be used, and a second time to determine what your payoff is for the option you chose, A or B, for the particular decision selected. Even though you will make ten or less decisions, only one of these will end up affecting your earnings, but you will not know in advance which decision will be used. Obviously, each decision has an equal chance of being used in the end.
- Your payoff from this round will range between \$0.1 and \$3.85.

Answer Recording Sheet **ID#:**

<u>Set II: Lottery Choice Game</u>

	Option A	Option B	Your Choice (circle one)
1	1/10 of \$2.00, 9/10 of \$1.60	1/10 of \$3.85, 9/10 of \$0.10	A , B
2	2/10 of \$2.00, 8/10 of \$1.60	2/10 of \$3.85, 8/10 of \$0.10	A , B
3	3/10 of \$2.00, 7/10 of \$1.60	3/10 of \$3.85, 7/10 of \$0.10	A , B
4	4/10 of \$2.00, 6/10 of \$1.60	4/10 of \$3.85, 6/10 of \$0.10	A , B
5	5/10 of \$2.00, 5/10 of \$1.60	5/10 of \$3.85, 5/10 of \$0.10	A , B
6	6/10 of \$2.00, 4/10 of \$1.60	6/10 of \$3.85, 4/10 of \$0.10	A , B
7	7/10 of \$2.00, 3/10 of \$1.60	7/10 of \$3.85, 3/10 of \$0.10	A , B
8	8/10 of \$2.00, 2/10 of \$1.60	8/10 of \$3.85, 2/10 of \$0.10	A , B
9	9/10 of \$2.00, 1/10 of \$1.60	9/10 of \$3.85, 1/10 of \$0.10	A , B
10	10/10 of \$2.00, 0/10 of \$1.60	10/10 of \$3.85, 0/10 of \$0.10	A , B

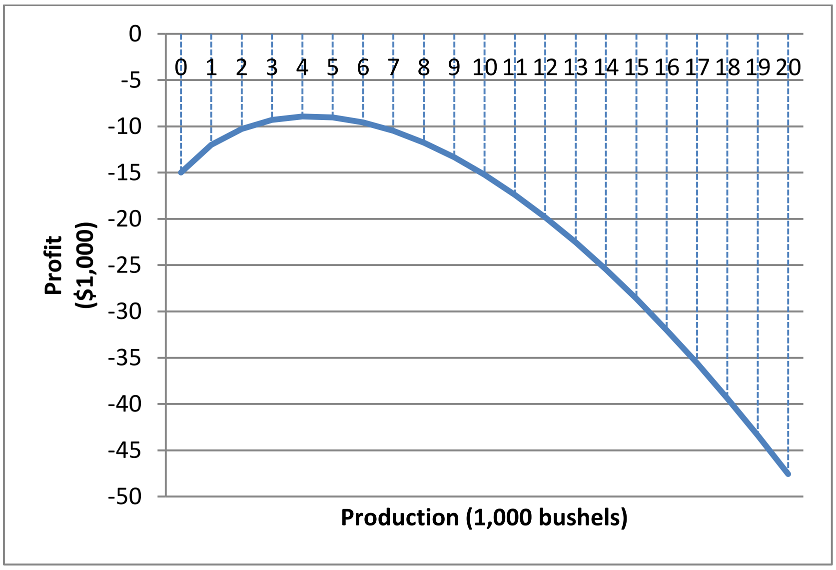
Stop once you have chosen the option B.

Thank you for your participation! ☺

2- Profit Charts and Settings

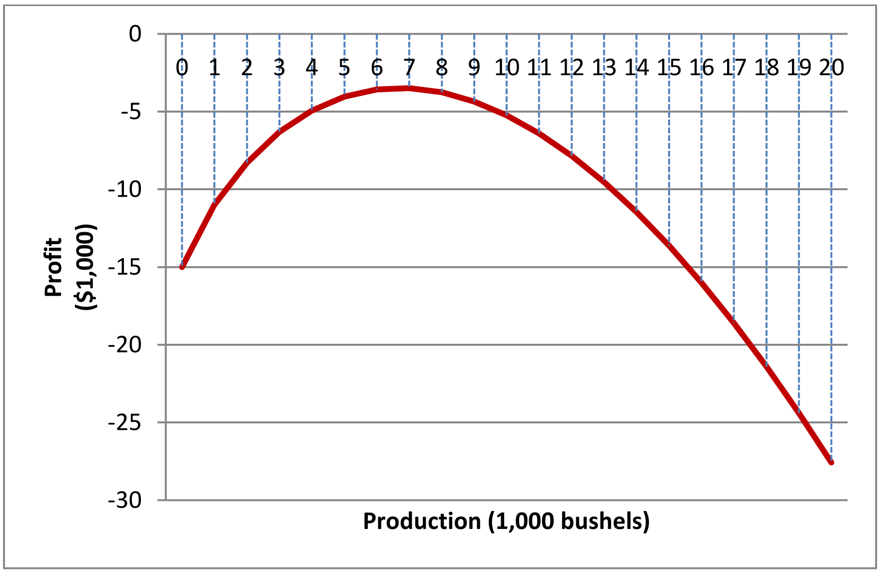
1. Wheat production, cost, and profit when price of wheat is **$5/bushel**.

(1) Wheat Production (1,000 bushels)	(2) Price ($/bushel)	(3) Cost $= 2 \times (1)^{1.4}+15$ ($ 1,000)	(4) Profit $= (1)\times(2)-(3)$ ($1,000)
0	5	15.00	-15.00
1	5	17.00	-12.00
2	5	20.28	-10.28
3	5	24.31	-9.31
4	5	28.93	-8.93
5	5	34.04	-9.04
6	5	39.57	-9.57
7	5	45.49	-10.49
8	5	51.76	-11.76
9	5	58.35	-13.35
10	5	65.24	-15.24
11	5	72.41	-17.41
12	5	79.85	-19.85
13	5	87.54	-22.54
14	5	95.47	-25.47
15	5	103.63	-28.63
16	5	112.01	-32.01
17	5	120.60	-35.60
18	5	129.40	-39.40
19	5	138.39	-43.39
20	5	147.58	-47.58



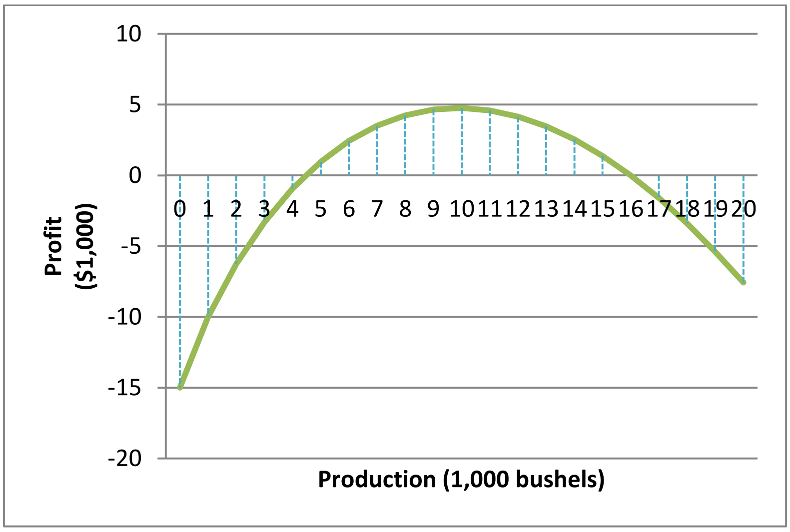
2. Wheat production, cost, and profit when price of wheat is <u>$6/bushel</u>.

(1) Wheat Production (1,000 bushels)	(2) Price ($/bushel)	(3) Cost = 2 X (1)$^{1.4}$+15 ($ 1,000)	(4) Profit = (1)X(2)-(3) ($1,000)
0	6	15.00	-15.00
1	6	17.00	-11.00
2	6	20.28	-8.28
3	6	24.31	-6.31
4	6	28.93	-4.93
5	6	34.04	-4.04
6	6	39.57	-3.57
7	6	45.49	-3.49
8	6	51.76	-3.76
9	6	58.35	-4.35
10	6	65.24	-5.24
11	6	72.41	-6.41
12	6	79.85	-7.85
13	6	87.54	-9.54
14	6	95.47	-11.47
15	6	103.63	-13.63
16	6	112.01	-16.01
17	6	120.60	-18.60
18	6	129.40	-21.40
19	6	138.39	-24.39
20	6	147.58	-27.58



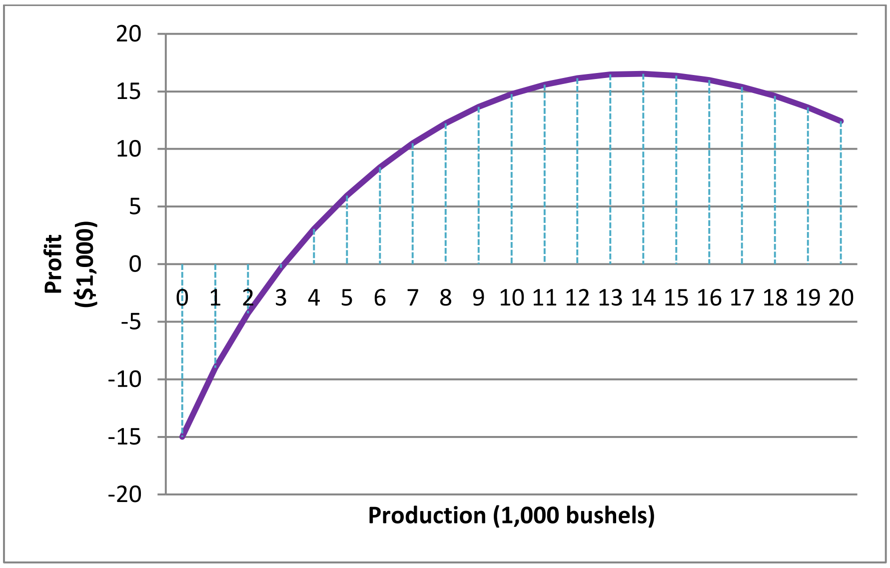
3. Wheat production, cost, and profit when price of wheat is **<u>$7/bushel</u>**.

(1) Wheat Production (1,000 bushels)	(2) Price ($/bushel)	(3) Cost $= 2 \text{ X } (1)^{1.4}+15$ ($ 1,000)	(4) Profit = (1)X(2)-(3) ($1,000)
0	7	15.00	-15.00
1	7	17.00	-10.00
2	7	20.28	-6.28
3	7	24.31	-3.31
4	7	28.93	-0.93
5	7	34.04	0.96
6	7	39.57	2.43
7	7	45.49	3.51
8	7	51.76	4.24
9	7	58.35	4.65
10	7	65.24	4.76
11	7	72.41	4.59
12	7	79.85	4.15
13	7	87.54	3.46
14	7	95.47	2.53
15	7	103.63	1.37
16	7	112.01	-0.01
17	7	120.60	-1.60
18	7	129.40	-3.40
19	7	138.39	-5.39
20	7	147.58	-7.58



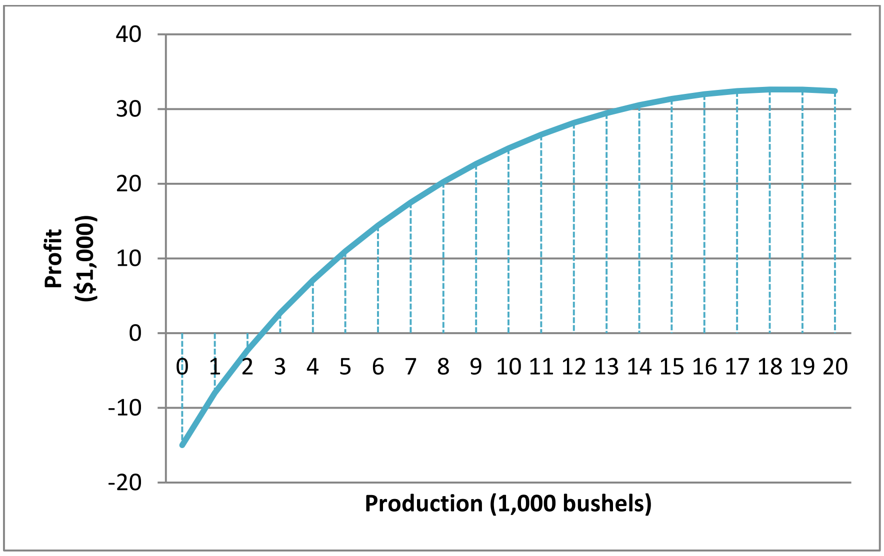
4. Wheat production, cost, and profit when price of wheat is **$8/bushel**.

(1) Wheat Production (1,000 bushels)	(2) Price ($/bushel)	(3) Cost = 2 X $(1)^{1.4}$+15 ($ 1,000)	(4) Profit = (1)X(2)-(3) ($1,000)
0	8	15.00	-15.00
1	8	17.00	-9.00
2	8	20.28	-4.28
3	8	24.31	-0.31
4	8	28.93	3.07
5	8	34.04	5.96
6	8	39.57	8.43
7	8	45.49	10.51
8	8	51.76	12.24
9	8	58.35	13.65
10	8	65.24	14.76
11	8	72.41	15.59
12	8	79.85	16.15
13	8	87.54	16.46
14	8	95.47	16.53
15	8	103.63	16.37
16	8	112.01	15.99
17	8	120.60	15.40
18	8	129.40	14.60
19	8	138.39	13.61
20	8	147.58	12.42



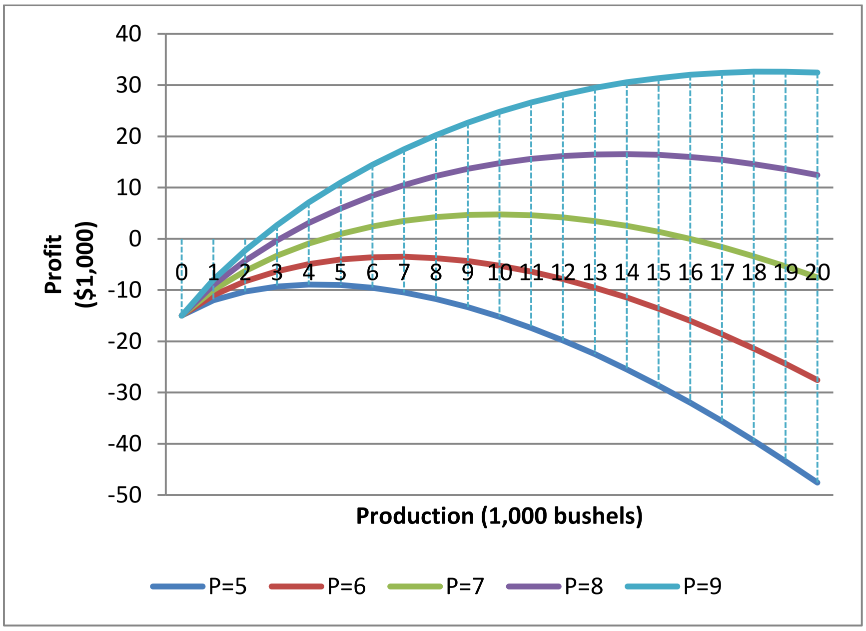
5. Wheat production, cost, and profit when price of wheat is **$9/bushel**.

(1) Wheat Production (1,000 bushels)	(2) Price ($/bushel)	(3) Cost $= 2 \times (1)^{1.4}+15$ ($ 1,000)	(4) Profit = (1)X(2)-(3) ($1,000)
0	9	15.00	-15.00
1	9	17.00	-8.00
2	9	20.28	-2.28
3	9	24.31	2.69
4	9	28.93	7.07
5	9	34.04	10.96
6	9	39.57	14.43
7	9	45.49	17.51
8	9	51.76	20.24
9	9	58.35	22.65
10	9	65.24	24.76
11	9	72.41	26.59
12	9	79.85	28.15
13	9	87.54	29.46
14	9	95.47	30.53
15	9	103.63	31.37
16	9	112.01	31.99
17	9	120.60	32.40
18	9	129.40	32.60
19	9	138.39	32.61
20	9	147.58	32.42



6. Profits when price of wheat is **$5/bushel-$9/bushel**.

Wheat Production	Profit				
	P = $5	P = $6	P = $7	P = $8	P = $9
0	-15.00	-15.00	-15.00	-15.00	-15.00
1	-12.00	-11.00	-10.00	-9.00	-8.00
2	-10.28	-8.28	-6.28	-4.28	-2.28
3	-9.31	-6.31	-3.31	-0.31	2.69
4	-8.93	-4.93	-0.93	3.07	7.07
5	-9.04	-4.04	0.96	5.96	10.96
6	-9.57	-3.57	2.43	8.43	14.43
7	-10.49	-3.49	3.51	10.51	17.51
8	-11.76	-3.76	4.24	12.24	20.24
9	-13.35	-4.35	4.65	13.65	22.65
10	-15.24	-5.24	4.76	14.76	24.76
11	-17.41	-6.41	4.59	15.59	26.59
12	-19.85	-7.85	4.15	16.15	28.15
13	-22.54	-9.54	3.46	16.46	29.46
14	-25.47	-11.47	2.53	16.53	30.53
15	-28.63	-13.63	1.37	16.37	31.37
16	-32.01	-16.01	-0.01	15.99	31.99
17	-35.60	-18.60	-1.60	15.40	32.40
18	-39.40	-21.40	-3.40	14.60	32.60
19	-43.39	-24.39	-5.39	13.61	32.61
20	-47.58	-27.58	-7.58	12.42	32.42



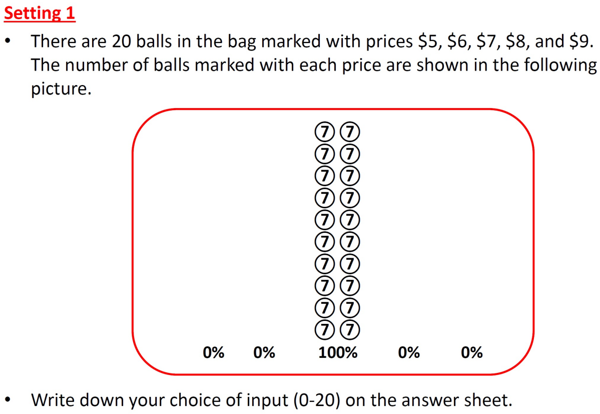


Figure 7: Setting 1

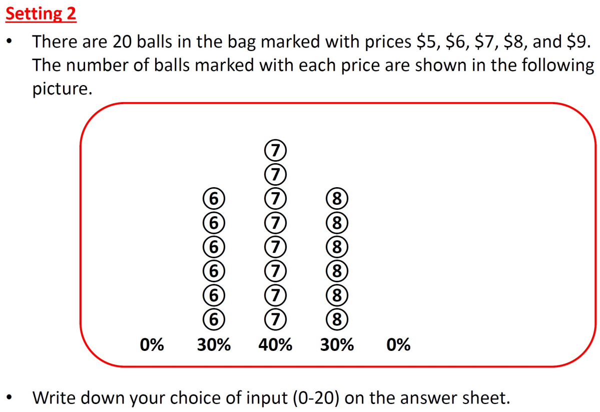


Figure 8: Setting 2

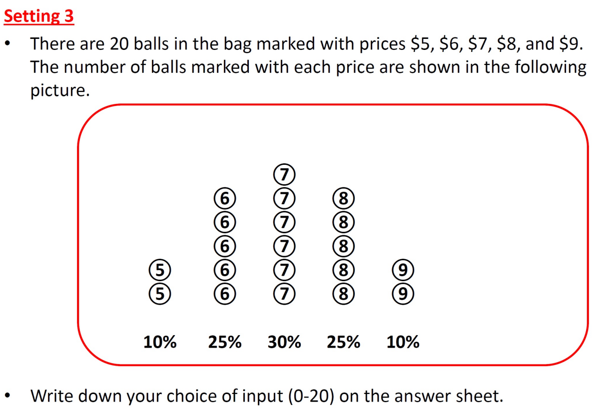


Figure 9: Setting 3

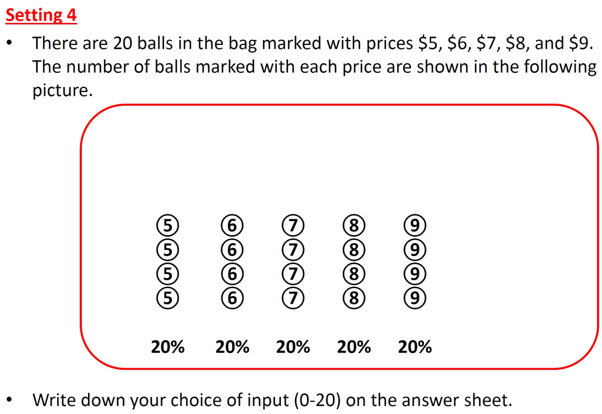


Figure 10: Setting 4

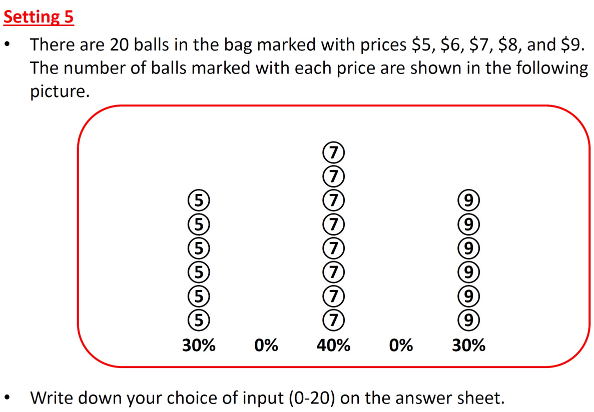


Figure 11: Setting 5